Target Polarization Measurements with a Crossed-Coil Polarimeter*

Anthony Caracappa and Craig Thorn
Brookhaven National Laboratory, Upton, NY 11973

Accurate target polarimetry is essential to polarized target experiments. We have performed a complete electronic circuit analysis of the crossed coil NMR polarimeter (CC-meter), and from this analysis we have determined the optimum conditions for its operation. These results are compared to the very well studied and more commonly used Q-meter circuit. The CC-meter replaces the single coil and resonant circuit of the Q-meter with a pair of coils arranged with orthogonal axes and a pair of associated resonant circuits. The tuned circuits are not essential, and the transmitter and receiver circuits can be operated with matched cables, at the expense of lower signal-to-noise ratio. In any practical realization, both the CC-meter and Q-meter polarimeters suffer from significantly non-linear responses for highly polarized samples. One important purpose of the circuit analysis is to specify conditions under which these become acceptably small, or to allow the computation of a correction to the polarization deduced from the electrical signals in the presence of significant non-linearities. Under conditions of operation that produce similar, small, non-linearities for the two circuits, we have found that the CC-meter has the following significant advantages over the Q-meter. By proper design, the inductive and capacitive coupling between the two coils can be made very small (-50dB), so that the background signal under the NMR resonance signal is very small. This leads to small systematic errors in the background subtraction, which result from the inevitable drift of the background during the long measurement time. Also, since most of the noise in these measurements comes from the RF signal source, the low background results in greatly improved signal-to-noise ratios for the polarization measurement with the CC-meter. The inductances and geometries of the two coils of the CC-meter can also be separately optimized to achieve specific requirements (such as RF field uniformity over the target) not possible with the typical embedded coils of the Q-meter. The only disadvantages of the CC-meter with respect to the Q-meter are the fact that two cables must enter the cryogenic volume and two resonant circuits must be tuned. We have also found that the filling factor (the fractional change in inductance per unit susceptibility) is a complex function of the complex susceptibility and that this is an important effect for the small filling factors encountered with the external coils typically used for the CC-meter. The CC-meter is optimized by keeping the coil couplings small, keeping the inductance of the receiver coil about twice that of the transmitter coil, keeping coil resistances low, using cables with high Q and high characteristic impedance, and using a low source impedance for the transmitter and a high input impedance for the receiver.

*This work was supported by the U.S. Department of Energy under contract DE-AC02-98CH10886.